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FINAL REPORT

STUDY OF FOUNDER-LIKE CHANGES IN THE HOOVES OF BEEF CATTLE UNDER INTENSIVE FEEDING CONDITIONS

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Study of Founder-Like Changes in the Hooves of Beef Cattle Under Intensive Feeding Conditions

a) Executive Summary

1. DATABASE ABSTRACT

A high percentage of crossbred Charolais steer calves fed high levels of energy immediately following weaning showed definite signs of founder. Furthermore, there was an excessive increase of sole horn thickness. Both of these findings had been previously observed in intensively fed pedigree beef bulls some of which had been culled for either laminitis or excessive hoof horn production. Crossbred steers that were given a backgrounding ration until they were approximately thirteen months of age and then fed the same rations as the calves did not show the same founder-like lesions nor did they demonstrate accelerated hoof horn growth.

2. LAY SUMMARY

The results of the study being reported show that important changes occurred in the claws of two groups of Charolais cross steers subjected to intensive feeding.

One significant finding was related to claw horn growth. We found that the thickness of the sole of the claw was estimated to increase at an average rate of 0.06 cm per month in control animals. By contrast, the soles of the claws of the calves (over eight months of age) increased in thickness at the rate of 0.16 cm per month while sole horn in the yearlings (over thirteen months of age) increased in thickness at a rate of only 0.05 cm per month. These findings show that the claw horn growth rate of the calves was over 2.5 times the estimated normal value. Bull calves in the Saskatoon R.O.P. station (1986-7) were culled because their claws were overgrown. Some top performers were eliminated. Based on this study, it would seem unwise to cull breeding bulls for the criterion of hoof overgrowth until further studies clarify the growth characteristics of the claws of entire male calves. It should be noted that hoof overgrowth did not occur amongst the group of animals which started intensively feeding when they were thirteen months of age.

In this study it was not possible to associate the excessive horn growth with any nutritional factor. The failure to make this association does not necessarily preclude nutrition as a cause. However, because the yearlings showed no abnormal horn growth, age must be considered the most important factor.

The significant management by protein interaction Figure 10, shows clearly that in yearlings the increase of sole horn thickness is reduced as dietary CP increases. The reason for this observation is unclear. Detailed chemical analysis of digital horn could provide an explanation. Hemorrhages of the sole is a finding that many workers associate with laminitis. A large proportion of the calves showed evidence of hemorrhage in the sole while the yearlings showed very little evidence of discoloration of the horn. Therefore, age also appears to have an influence on the occurrence of sole

hemorrhages. However, calves fed the high energy rations show higher average daily weight gains and a significantly higher incidence of hemorrhages in the toe area than those fed the low energy rations. Thus, with rapidly growing, young animals, the energy level appears to influence the soundness of the foot. Hemorrhage in the hoof and lameness caused by founder has been observed in R.O.P. bulls that were culled for reasons of "feet and Legs". It has been reported that once an animal has suffered from an attack of laminitis, it can be more susceptible to a second attack. We could assume that severely or repeatedly affected animals could suffer damage that could be permanent.

Growth is controlled by physiological and hormonal mechanisms. The reduced incidence of hemorrhages in yearlings and the excessive sole horn growth in calves occurred at a time at which entire males would be entering puberty. This may be a further argument that intensively fitting bulls during puberty may be unwise.

It was found that the tip of the bone in the hoof of many of the yearlings had turned downwards to press on the sole. This change was virtually absent from the feet of the calves. "Rotation" of the hoof bone is an irreversible process and a serious change that would make an affected animal "unsound". Phalangeal rotation as observed in the yearlings is of little consequence in animals destined for slaughter, but could have very serious implications if it were to occur in bulls or heifers of the same age intended for use in the breeding herd. Some of the yearlings that showed rotation of the bone also had a pronounced ridge on the surface of the claw wall. One worker has stated that ridges of the wall are closely related to other laminitis-like changes in the corium.

The cause of the rotation and the ridging is puzzling. It seems possible that the events leading up to the two changes occurred at the same time, occurred suddenly and were over quickly. The changes seen in the calves seemed to occur over a long period.

In summary, it is interesting to note some of the ways in which the calves differed from the yearlings:

1) The calves were approximately six months younger than the yearlings when they started intensive feeding. Growth and factors controlling growth could be the key to eventually understanding the differences observed between calves and yearlings.

2) The average number of days of intensive feeding for the yearlings was 114 and for the calves 144.

3) The preweaning ration was unknown. The yearlings were fed a restricted ration before making a transition to ad lib feeding of barley silage and grain. The influence of fiber was not a factor considered in this study but some workers believe that the quality and quantity of fibre in a ration have an important influence of the occurrence of founder.

Evidence from this study shows that the practice of intensively feeding steers before they have reached fourteen months of age is deleterious to their digital soundness. Even when this age has been reached it seems that care must be taken to avoid sudden or dramatic changes in the feeding management. Bulls and heifers could be affected in the same manner if subjected to similar feeding regimens. Clinical experience suggests that if the pathological changes were as serious as was observed in some cases it is probable that permanent unsoundness could be the result.

b) Papers prepared.

i. Laminitis related unsoundness of intensively fed beef cattle.
P. Greenough, J. Vermunt, F. Fathy, P. Berg, J. McKinnon, R. Cohen.
Submitted to the Canadian Veterinary Journal, April 1989.

ii. A bovine hoof corium biopsy technique for the identification of inflammatory changes.
P. Greenough, F. Fathy, E. Campbell

In preparation

iii. Changes in the organic and inorganic composition of bovine hoofhorn during periods of intensive feeding.
J. Vermunt, P. Greenough, D. Bailey (Alberta AG)

Analysis incomplete but paper in draft.

Talks Given 1989

Bull Evaluation. Pasture Manager Conference, Saskatoon.

Feet and Leg Problems. S.V.M.A. Mid-Winter Convention.

1988 Recent Developments in Understanding Bovine Lameness.
Canadian Veterinary Medical Association Convention.

Contemporary concepts in bovine lameness, University of Pennsylvania Annual Conference.

1987 Laminitis Fact or Fiction. British Veterinary Association Conference, Warwick, UK

Sub-clinical laminitis. Royal Danish Agriculture and Veterinary Institute, Copenhagen, Denmark

Feet and Fodder. Alberta Agriculture Conference, Banff

A review of diseases of the bovine digital region,
Andalusian Veterinary Academy, Barcelona, Spain.

c) A verified statement of expenditures to be provided by the University of Saskatchewan accounting department after July 1, 1989.

d) Personnel time involvement

P. Greenough	15%
F. Fathy	100%
M. Ogunyele	50%
J. Vermunt	15%
J. McKinnon	5%
R. Cohen	1%
P. Berg	5%

Also time of various workers employed by the Department of Animal and Poultry Science.

e) Equipment purchases over $500

f) i. Olympus microscope ii. Shore meter (for measuring hoof horn hardness)

LAMINITIS RELATED UNSOUNDNESS

OF

INTENSIVELY FED BEEF CATTLE

Paul Greenough FRCVS
Jos Vermunt DVM, BAgSc, MACVSc
Fowzy Fathy BVMS, MS, PhD
Philip Berg BSc
John McKinnon BSA, MSc
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SUMMARY

Two hundred and fifty eight beef steer calves (approximately eight months old) and 200 yearlings (approximately thirteen months old) were fed rations containing two levels of energy (73.5 and 78.5% TDN) and six levels of crude protein (11,13,15, 16,17,and 19% CP).

At slaughter, a high proportion of the claws of the animals showed lesions that were indistinguishable from sub-clinical laminitis. Sole horn thickness for the calves measured 1.20 cm; that for the yearlings 0.90 cm ($P<0.01$). The sole horn growth rate was two and one half times normal for the calves but normal in the yearlings. Sole horn thickness decreased with increasing dietary protein levels in the yearlings ($P<0.02$). Mean toe and heel hemorrhages were significantly higher in the calves than the yearlings ($P<0.01$). Across energy levels both toe and heel hemorrhages increased significantly with increasing dietary energy levels ($P<0.01$ and $P<0.02$ respectively). Calves fed the highest energy level had highest mean hemorrhage scores ($P<0.01$).

In the yearlings, rotation of the distal phalanx and ridging of the dorsal wall of the claw were the most prominent pathological features ($P<0.01$). Osteopathy of the apex of the distal phalanx was observed in both groups but more frequently in the calves ($P<0.01$). In 66% of 32 calves examined regularly throughout the study, erythema was observed through the horn of the dorsal wall of the claw. The incidence of liver abscesses was 23.4% in both groups.

This study suggests that intensive feeding of beef cattle before they reach fourteen months of age, will have deleterious effects on their digital soundness. Although the exact etiology of the laminitis-like lesions observed is not fully understood, possible causes are discussed.

INTRODUCTION

Historically, laminitis was first recognized and researched in horses. The clinical signs of acute and chronic laminitis are well known (1) and rotation of the distal phalanx or "dropped sole" is a serious sequel. Obel (2) reported his findings concerning the histopathology of equine laminitis in 1948. The endotoxin theory for the etiology of laminitis culminated with the work of Garner et al. (3). There is agreement in the more recent literature that the acute phase of equine laminitis is due to a severely disturbed micro-circulation in the epidermis and corium (4-6). The central issue of what might be the cause and nature of the disturbed hemodynamics of these tissues is still unanswered (7). If the disturbance in the circulation is severe enough (e.g. due to extensive thrombosis which is frequently observed in cases of acute laminitis (8)), recovery is not likely to occur.

It was assumed for many years that laminitis in horses and cattle was the same phenomenon. Nilsson's classic study of this disorder in cows was published in 1963 (9). The majority of studies of laminitis in cattle involved dairy cattle (9-17). Phalangeal rotation has been reported in cattle (9,18,19).

Laminitis in beef cattle has been reported (20-23). However, the amount of published research is very limited (24).
Osteoporotic changes in the tip of the distal phalanx have been described in young beef cattle that were fed barley and suffered from laminitis of several weeks duration (21).

The phenomenon of "sub-clinical laminitis" was not recognized until 1979 when Peterse described the syndrome in dairy cattle (25). The sole of the hoof had a yellow, waxy, blood stained appearance and the texture of the horn was softer than normal. Since then, more knowledge concerning this condition has been gathered, mostly in Europe (15,26-29) but also in North America (30-33). The incidence of digital disease has been shown to increase relative to the presence of abnormally textured horn which is characteristic of sub-clinical laminitis. It should be noted that, although sub-clinical laminitis is reported extensively in the literature, again, it refers mostly to work with dairy cattle.

Digital unsoundness of young, intensively fed breeding bulls was observed during a performance test carried out in the winter of 1985-6. Eighteen percent of the highest performing beef bulls were eliminated for reasons involving "feet and legs". Eighty-four percent of these rejected bulls were found to be affected with laminitis (20). Bulls tested during the following winter, (1986-7), did not present signs of clinical laminitis. However, the abberations of gait were on this occasion, clinically assessed as being caused by an excess production of digital horn. These observations justified an investigation which utilized 500 beef steer calves, that were being used for intensive feeding trials,

in order to study changes to the digital horn and corium. The rationale for the study was to gain information that would be useful in recognizing and understanding similar changes that might occur in the claws of young breeding cattle.

The objective of the study was:

To describe and quantify abnormalities that occur in the claws and corium of young intensively fed beef cattle managed under two regimens and given rations that varied in energy and protein level.

MATERIALS and METHODS

A. Animals

Five hundred Charolais cross steer calves, approximately eight months of age, were purchased from commercial sources in October 1987. The steers were managed in two different ways.

Group One "Calves" (258 animals)

Two hundred and sixteen steer calves weighing 278-354 kg, were randomly assigned to twenty-four pens. Nine animals were allocated to each pen and fed one of twelve rations. Each ration was formulated from similar ingredients to one of two energy levels (73.5% total digestible nutrients (TDN) or 78.5% TDN) and one of six crude protein (CP) levels (11,13,15,16,17,and 19%).
Prior to the start of test all animals were given an adjustment period (approximately 28 days) to adapt to the feedlot and the experimental rations. The animals were slaughtered when the backfat measured approximately 7mm (using ultrasound equipment). Therefore, the time from start to slaughter differed between animals. Ten calves were slaughtered prior to the commencement of the feeding trial, serving as "calf-controls".

Thirty two of the heaviest steer calves with an initial weight ranging from 301 to 384 kg were distributed among four pens to be fed one of four rations representing the extremes of the previously described energy/protein combinations. Included were high energy/high protein, high energy/low protein, low energy/high protein and low energy/low protein. Each week for eight weeks, biopsy samples of the sub-lamellar corium of the dorsal toe area were taken from one animal in each of these pens. This sub-group of thirty-two animals was referred to as "calf-biopsy" group.

Group Two "yearlings" (200 animals)

Two hundred steers were placed in a "backgrounding program". They were fed a ration which allowed an average daily weight gain of 0.45 kg. After 166 days, 192 of these animals were treated and fed in exactly the same manner as group one (calves). At this time they weighed from 309 to 414 kg. Eight randomly selected steers were

slaughtered at this stage serving as "yearling-controls" .

B. Collection and evaluation of samples

The "control-animals" were slaughtered at the beginning of each phase of the trial and the digits of the left pelvic limbs were harvested. When the "calves" and the "yearlings" were slaughtered the digits of the left pelvic limbs were harvested so far as was practical. As soon as possible after slaughter (10 minutes to 3 hours) a 0.5 cm sagittal section of the lateral claw was cut, using a band saw, 2 cm from and parallel to the axial wall of the claw. This section was photographed against a centimetre scale. Four 0.5 cm blocks of the wall and sole including the attached corium were cut from sites modified from those previously described by Andersson and Bergman (18)(Fig 1). The samples were fixed in 10% neutral formol saline. Evaluation of photographs or specimens was carried out blindly.

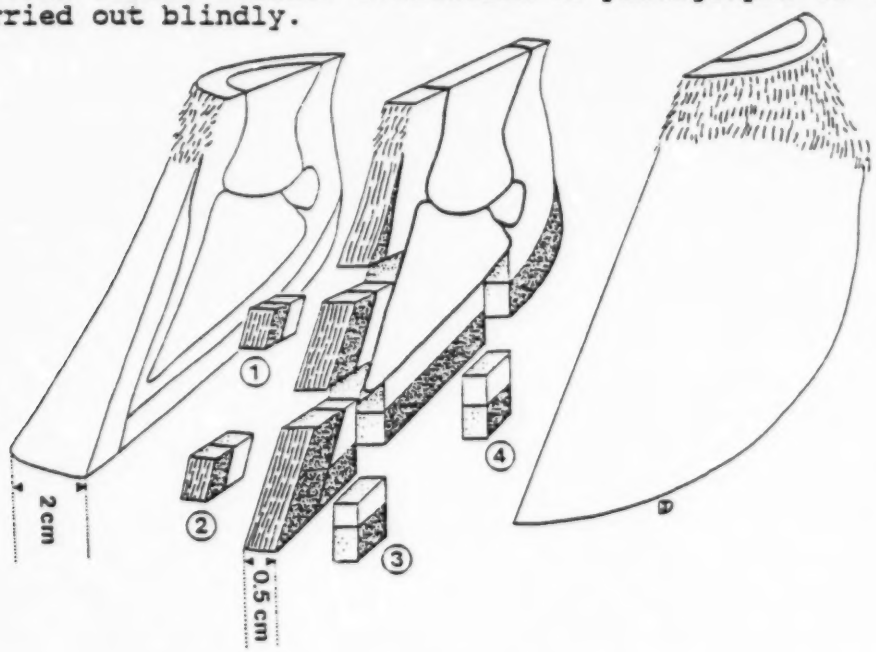


Fig 1. Sagittal section of the lateral claw of the left pelvic bovine limb taken two centimeters from and parallel to the axial wall. Blocks for histopathological examination: 1, proximal dorsal wall segment (1 cm below the coronary band); 2, distal dorsal wall segment (2 cm above the wall-sole junction); 3, sole segment (3 cm posterior to the wall-sole junction); 4, heel segment (at the sole-heel junction).

HISTOPATHOLOGY

The samples from the four regions described above were paraffin blocked, cut at 5 µm, and stained with haematoxylin and eosin.

MACROPATHOLOGY

The photographs of the longitudinal sections of the digits were evaluated in accordance with the following protocol:

a) Thickness of the sole. Measurements were taken at a point 3 cm caudal to the internal apex of the sole (Fig 2 & 3).

b) Hemorrhages in the sole. A semiquantitative, subjective score of 0 to 5 was developed to evaluate the severity of the hemorrhages. The scale indicates the percentage of the profile of the sole that showed any trace of red discoloration as follows:

0 = No hemorrhage
1 = <10%
2 = 10 - 20%
3 = 20 - 40%
4 = 40 - 80%
5 = >80%

Separate evaluations were made for the cranial and caudal halves of the sole. The line of demarkation between the two being set immediately distal to the podotrochlear joint. The scores recorded represented hemorrhage severities in the toe and heel area respectively (Fig 3).

c) Rotation of the distal phalanx (Fig 4). The criteria used to support the observation of positive rotation of the phalanx were:

i) Deviation of the apex of dorsal surface of the distal phalanx from the lamellar surface of the wall of the claw.
ii) Moulding of the sole beneath the apex of the distal phalanx.
iii) Compression of the corium located between the sole and the apex.

d) Presence of ridging on the dorsal wall of the toe (Fig 5).

e) Changes in the bone structure (osteopathy) of the apex of the distal phalanx (Fig 6).

The incidence of rotation, ridging, and osteopathy was recorded on the basis of the management groups only (calves and yearlings). Photographs of cross sections of digits were not used if the cross sections of the digits did not match in general appearance. The profile of the internal architecture, as seen in cross section, differs considerably depending on the plane of sectioning. Therefore, it is of critical importance that the digits are sectioned through exactly the same plane in order to evaluate the material objectively.

RADIOGRAPHY AND GROSS PATHOLOGY

After slaughter twenty-two randomly selected medial claws of the yearling group were radiographed for evidence of osteopathy. (Fig 7 & 8).

The presence of liver abscesses was recorded at slaughter.

CLINICAL EVALUATION

a) Health history. The animals were monitored for evidence of lameness and shipping fever.

b) "Erythema", when visible through the dorsal wall of the toe, was recorded for the "calf-biopsy" group (Fig 9).

CALCULATIONS AND STATISTICAL ANALYSIS

For group one (calves), sole horn growth rates were calculated based on mean sole horn thickness at slaughter minus the mean sole horn thickness of the calf-control group divided by the mean days on feed. Similar calculations were carried out for group two (yearlings) using the yearling-controls as a base line.

The normal growth rate for sole horn was estimated by subtracting the mean sole horn thickness of the calf-control group from the mean sole horn thickness of the yearling-control group divided by the number of days of backgrounding. In order to estimate the sole thickness of the calves, had the calves not been intensively fed (ie the projected sole thickness), the normal daily growth rate multiplied by the mean days on feed was added to the mean sole thickness of the calf-controls. Similar calculations were made for the yearlings.

The data were analyzed as a 2 x 2 x 6 factorial, using each pen of animals as a single observation. The unbalanced nature of the data was accommodated using the general linear model (GLM) procedure of SAS (34). Means were separated by Student-Newman-Keul's procedure (35). The incidence of rotation, ridging and osteopathy was compared between management groups by Chi-square analysis (35).

Fig 2. The profile of a section of the distal phalangeal region of a normal extremity.

Fig 3. A section of the sole of a calf that has been fed intensively. The sole is much thicker than normal. The hemorrhages are typical of sub-clinical laminitis. Note the layering of the discoloration which suggests that insults have occured intermittently. This could indicate the "episodic" nature of the condition.

Fig 4. A section of the digit of an intensively fed yearling showing early rotation of the distal phalanx. Notice the compression of the corium beneath the apex of the distal phalanx and the slight moulding of the sole (arrowhead). The dorsal surface of the distal phalanx has deviated from the parallel with the inner surface of the hoof wall. Note the presence of a marked ridge ("y").

Fig 5. The external surface of the claw of a yearling. The groove marked "x" was created at the time of weaning. As the wall has grown this groove has moved distally and is no longer present in some animals of the this age. The ridge marked "y" was created at the time that the animal was introduced to intensive feeding. It has also moved distally as the wall has grown.

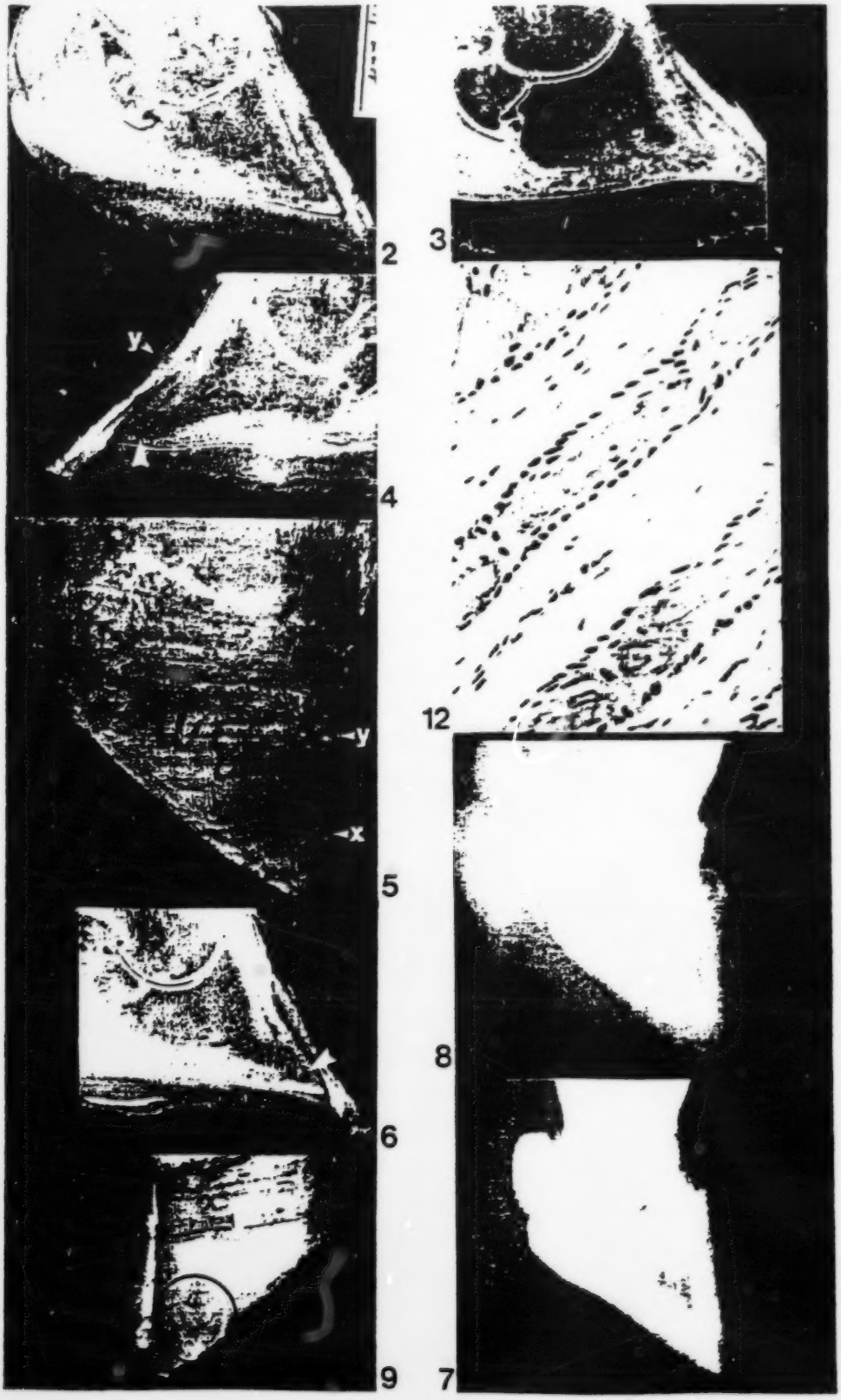
Fig 6. A section of the digit of an intensively fed yearling showing loss of definition of the apex of the distal phalanx (arrowhead). This indeterminate change is referred to as osteopathy in the text.

Fig 7. A radiograph of a normal medial digit from a pelvic limb.

Fig 8. A radiograph of a medial digit taken from an intensively fed yearling showing rarification of the bone at the apex of the distal phalanx.

Fig 9. The lateral claw from an intensively fed calf. A slightly pink discoloration can be observed through the horn on the distal dorsal region. This is referred to as "erythema" in the text. Note the presence of a weaning groove "x".

Fig 12. A histological section of the lamellae of an intensively fed calf shows loss of organization of the stratum basale cells and keratin changes that could be compatible with those described in the literature.


2
y
4
y
x
5
6
9
3
12
8
7

RESULTS

The feeding regimen employed in the test was found to influence a number of clinical parameters (Table 1).

Table 1. The effect of management and dietary energy level on sole horn thickness, the incidence of toe and heel hemorrhages and liver abscesses in intensively fed steers.[1]

	MANAGEMENT		DIETARY ENERGY (% TDN)	
PARAMETER	CALVES	YEARLINGS	73.5	78.5
SOLE HORN THICKNESS	1.20 [a]	0.90 [b]	1.02	1.07
TOE HEMORRHAGES	0.84 [a]	0.05 [b]	0.19 [a]	0.66 [b]
HEEL HEMORRHAGES	1.23 [a]	0.27 [b]	0.42 [a]	1.04 [b]
LIVER ABSCESSES	0.21	0.24	0.20	0.26

1 a,b within management and dietary energy, means within a row with different letters are significantly different (P<0.02).

A. Sole horn growth

Normal rate of sole horn growth was estimated to be 0.06 cm per month.

The projected thickness of the soles of the calves was 0.65 cm and for the yearlings 0.92 cm. A sole horn growth rate of 0.16 cm per month was calculated for the calves. In contrast, the yearlings had a calculated monthly sole horn growth rate of 0.05 cm. This resulted in respective mean sole horn thicknesses at slaughter of 1.20 and 0.90 cm; the difference being significant (P<0.01). Calves had a sole horn growth rate 2.5 x the normal value of 0.06 cm per month which was calculated for this trial.

The results did not demonstrate that dietary energy had any influence on growth of sole horn in either calves or yearlings. A significant management by protein interaction (P<0.02) was observed. Regression analysis indicates that the nature of this interaction was such that yearlings showed a reduction in the increase of sole horn thickness (Y) as dietary CP (X) increased:

$$Y = 1.35 - 0.03\ X \quad (r^2 = 0.81, \quad P<0.02)$$

while calves showed no such influence (Fig 10).

B. Hemorrhages in the sole of the hoof

Sole hemorrhages were evaluated separately for the toe and the heel region. Both were found to be significantly influenced by management (i.e. age and backgrounding) and energy level. When analyzed within management group, mean toe hemorrhage scores were significantly different; 0.84 and 0.05 for the calves and yearlings, respectively ($P<0.01$). Across energy levels, mean toe hemorrhage scores also showed a significant difference; 0.19 and 0.66 for the 73.5 and 78.5% TDN rations, respectively ($P<0.01$). Furthermore, a significant management by energy level interaction was detected ($P<0.01$); the characteristics of which is illustrated in Figure 11. Calves fed 78.5% TDN had higher mean toe hemmorrhage scores (1.32) than those fed 73.5% TDN (0.35) ($P<0.01$). In contrast, yearlings fed 78.5% TDN had similar scores to those fed 73.5% TDN (0.06 and 0.04 respectively).

Mean heel hemorrhage scores between management groups were significantly different; 1.23 and 0.27 for the calves and yearlings, respectively ($P<0.01$). The difference also being significant across energy levels where the mean heel hemorrhage scores were found to be 0.42 and 1.04 for the 73.5 and 78.5% TDN diets, respectively ($P<0.02$). In contrast to toe hemorrhages no significant management by energy interaction was detected.

There was no influence seen on either toe or heel hemorrhages with increasing protein level.

C. Liver abscesses

There was no effect of management, energy or protein level on the incidence of liver abscesses. The average incidence of liver abscesses in each group was 23.4% (Table 1).

D. Rotation and osteopathy of the distal phalanx and ridging of the dorsal wall of the digit

The incidence of rotation and ridging in yearling steers was greater than in calves ($P<0.01$), while the incidence of osteopathy was greater in calves than yearlings ($P<0.01$) (Table 2).

Table 2. The incidence (%) of rotation, ridging and osteopathy in two groups of intensively fed steers.[1]

	MANAGEMENT	
PARAMETER	CALVES (N=79)	YEARLINGS (N=74)
ROTATION	6 [a]	58 [b]
RIDGING	19 [a]	72 [b]
OSTEOPATHY	33 [a]	12 [b]

Four of the 22 radiographed medial claws showed signs of osteopathy of the apex of the distal phalanx.

E. Erythema beneath the dorsal hoof wall

In the calf-biopsy group erythema was observed through the wall of the distal dorsal region of the toe. Erythema was first observed fourteen days after the commencement of intensive feeding. It increased in frequency until after the seventieth day of the trial, when 66% of the animals showed pink coloration through the wall. The biopsy samples confirmed that vascular dilation and/or congestion occurred. There was no sign of lameness recorded during the study.

F. Shipping fever

The data for the incidence of shipping fever showed that all cases occurred during the adjustment period and showed no apparent influence on average daily weight gain.

None of the control calves or yearlings showed any abnormalities of the claws, epidermis or corium.

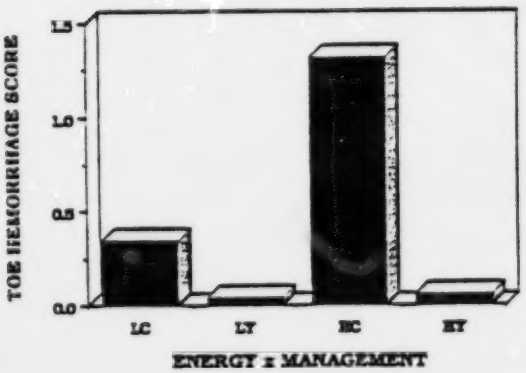


Figure 11. The effect of management and dietary energy level on the incidence of toe hemorrhage score of intensively fed beef steers (L=71.5% TDN; H=78.5% TDN; C=Calves; Y=Yearlings).

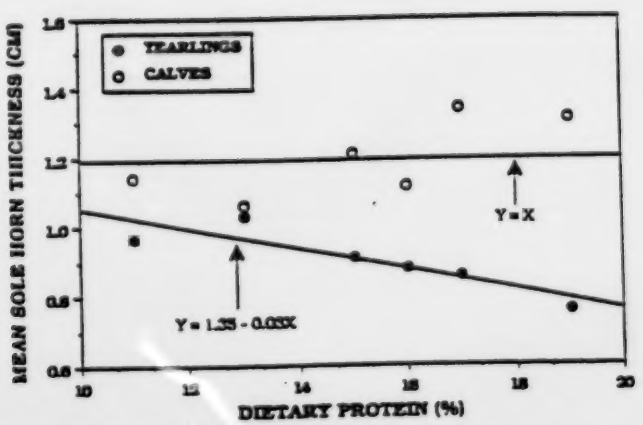


Figure 10. The effect of dietary protein on sole horn thickness of calves and backgrounded yearlings.

DISCUSSION

The results of the study being reported here show that pathological changes occurred in the claws and corium of young beef cattle subjected to intensive feeding.

A significant finding was related to claw horn growth. It has been reported that the claw wall grows at a rate of 0.4-0.5 cm per month (19,36,37). No information could be found reporting the rate of growth of sole horn. In this study, the thickness of the sole of the claw was estimated to increase at an average rate of 0.06 cm per month in the control animals. By contrast the soles of the claws of the test calves increased in thickness at the rate of 0.16 cm per month while sole growth in the yearlings increased at a rate of only 0.05 cm per month. This resulted in a mean sole thickness at slaughter of 1.20 cm (projected 0.65 cm) for the calves and 0.90cm (projected 0.92) for the yearlings.

These findings show that the claw horn growth rate of the calves was over 2.5 times the estimated normal value. It should be recalled that the bull calves culled in the winter of 1986-7 were eliminated because their claws were overgrown. Based on this study, it would seem unwise to cull such animals until further studies clarify the growth characteristics of the claws of entire male calves. However, if a genetic predisposition towards excessive claw horn growth does exist, culling for this factor could be a meaningful selection criterion of yearling bulls.
In this study it was not possible to associate the excessive horn growth with any nutritional factor. The failure to make this association does not necessarily preclude nutrition as a cause, however, because the yearlings showed no abnormal horn growth, age must be considered the most important factor.

The significant management by protein interaction illustrated in Figure 10, shows clearly that in yearlings the increase of sole horn thickness is reduced as dietary CP increases. The reason for this observation is unclear. Detailed chemical analysis of digital horn could provide an explanation.

Hemorrhages of the sole is a finding that many workers associate with laminitis (9,10,15,25-33). Although the observed hemorrhages were in some cases severe, it was not possible to detect any remarkable abberations of gait in the living animals. Animals with sub-clinical laminitis are by definition, never lame. Therefore, the hemorrhages were compatible with a diagnosis of sub-clinical laminitis.

There was a significant difference in the incidence of sole hemorrhages (both toe and heel) between the calves and the yearlings. Therefore, age also appears to have an influence on the occurrence of sole hemorrhages. However, calves fed high energy rations show higher average daily weight gains (38) and a

significantly higher incidence of toe and heel hemorrhages than those fed low energy rations. Thus with rapidly growing, young animals, energy level also appears to influence digital health. Sole hemorrhage is a characteristic correlated to laminitis and it has been suggested that the more frequent the insult the more profound the effect (26). Using this principle we can assume that a severely affected animal (Fig 3) would suffer damage that could be permanent.

The components of gain (i.e. muscle, fat and bone) of intensively fed yearling cattle, which had been backgrounded at low rates of gain for an extended period, would differ from that of intensively fed calves placed directly on feed if compared at similar weights or time on intensive feed (39). Furthermore, unpublished evidence (38) suggests that the composition of gain during the early phase of feeding of yearling cattle may have been influenced by compensatory gain. Growth and its resultant components is controlled by physiological and hormonal mechanisms. The reduced incidence of hemorrhages in yearlings and the excessive sole horn growth in calves may be manifestations of these mechanisms operating in cattle aged from eight to thirteen months. It is interesting to note in this context, that a recent report by Ekfalk et al. (40) demonstrated the presence of receptors for epidermal growth factor (EGF) in the corium. EGF stimulates mitosis but inhibits the differentiation of certain target cells including keratinocytes (41). Possibly, excessive horn growth, as was found in the calves, could be explained by EGF activity.

The high incidence of liver abscess in both groups points to the possibility of an associated rumenitis (42-45). An incidence of 22 % has been reported in "barley beef" cattle in the UK (46). The incidence of liver abscesses in feedlot cattle in the USA has been reported to be 18-20 % (43). The percentages of affected livers in both management groups (23.4%) are in agreement with these reports. Rumenal tissue samples were not taken in this study, therefore, no scores for the height and width of the rumen epithelium (a measure of rumenal parakeratosis) are available. Rumenitis and rumenal parakeratosis can result from rumenal acidosis which could be compatible with the theory of endotoxemia (47-50). On the other hand, EGF is released into the bloodstream from the organs of synthesis, such as the gut, at higher than normal levels in association with certain deleterious conditions of these organ systems (40,51). Rumenal acidosis could provide an appropriate tissue insult.

The normal histology of the lamellar area of the claw has been described by Dirks (52). The histopathological studies of laminitis reported in the literature have been based on necropsy material taken from acute or chronic cases of the condition (9,18,53,54). We are therefore cautious in interpreting our findings because the histopathological characteristics of sub-

clinical laminitis have not been previously reported. The histopathological changes observed in this study were similar to some of those reported in descriptions of both chronic and acute laminitis. These findings tend to support the diagnosis of sub-clinical laminitis.

The lamellar changes observed (Fig 12) have been described as a sign of laminitis (18,53). Dilation and/or engorgement of blood vessels which is indicative of blood pooling in the claw was also observed. Classical descriptions indicate that blood vessel damage and stasis of blood are considered to be precursors of thrombus formation and tissue necrosis (55,56). This was observed in a few sections. Hypoperfusion of the corium resulting in a relative tissue hypoxia could explain lamellar changes. It is generally agreed that a gastro-intestinal disorder, such as rumenal acidosis, can lead to severely disturbed hemodynamics in the digit.

Only occasional inflammatory cell infiltration of the dermal tissues was detected. Inflammation per se appears not to be a characteristic of the examined tissue samples. Therefore, the term laminosis might be more appropriate to describe the manifestation of sub-clinical laminitis observed in this study.

The finding of phalangeal rotation was important as it has been reported in association with both acute and chronic laminitis in cattle (9,18,19,21). However, the significantly higher incidence of phalangeal rotation seen in the yearlings is unique and puzzling. Rotation of the distal phalanx is an irreversible process and therefore represents a serious pathological change that would render an affected animal "unsound". Phalangeal rotation as observed in the yearlings is of little consequence in animals destined for slaughter, but could have very serious implications if it were to occur in bulls or heifers of the same age intended for use in the breeding herd.

McLean (21) reported that osteoporosis (a form of osteopathy) of the tip of the distal phalanx occurred in barley fed beef cattle affected with laminitis. Radiographically, osteopathy appeared to be present in four of 22 medial digits of left pelvic limbs that were randomly selected from the yearling group. The damage of the bony structures of the digit could be caused by an impaired bloodsupply in that particular region.

The effect of stress at weaning is recorded as a groove which will move distally from the coronary band at a rate of 0.4 - 0.5 cm per month (Fig 5 & 9). This phenomenon was seen in all of the calves and some of the yearlings. A similar phenomenon is reported in association with calving, but this has received only passing consideration in the literature (26,57).

A different type of ridge also affects the dorsal surface of the claw wall. This ridge, also runs approximately parallel to the

coronary band. However, in this case, the horn appears as a mass slightly elevated above the normal level of the claw wall. The production of this mass may be compatible with a process stimulating horn growth. Ridging was present in 19% of the calves and 72% of the yearlings. Boosman states that ridges of the dorsal wall are significantly correlated with vascular changes in the corium (57).

Erythema of the dorsal toe area of the claw was first observed in the calf-biopsy group 14 days after the commencement of intensive feeding. Erythema occurred with increasing frequency until the seventieth day of the test at which point 66% were affected. It was found that if erythema was seen there was a probability in excess of 60% that the histopathological picture would be one of vascular dilation and/or congestion. This is another finding suggesting disturbed digital hemodynamics.

In summary, the two management groups showed marked differences in lesions associated with laminitis. Hemorrhages of the sole, rapid claw horn growth and osteopathy were not as prominent in the yearlings compared to the calves despite identical feeding regimens. Rotation of the distal phalanx and ridging of the dorsal wall of the claw were the main features of the digital pathology of the yearlings.

The two groups differed in several respects:
1) The calves were approximately six months younger than the yearlings when they started intensive feeding. Growth and factors controlling growth could be the key to eventually understanding the differences observed between calves and yearlings.

2) The average number of days of intensive feeding for the yearlings was 114 and for the calves 144.

3) The fiber content of the preweaning ration was unknown. The yearlings were fed a low energy, relatively high fiber ration before making a transition to barley silage and grain. The influence of fiber was not a factor considered in this study but Peterse believes that fiber quality plays a highly important role in the etiology of sub-clinical laminitis (14,25-28).

Evidence from this study shows that the practice of intensively feeding steers before they have reached fourteen months of age is deleterious to their digital soundness. Bulls and heifers could be affected in the same manner if subjected to similar feeding regimens. Clinical experience suggests that if the pathological changes were as serious as was oberved in some cases it is probable that permenant unsoundness could result. Further research is required to determine if similar lesions occur in intensively reared breeding bulls and heifers.

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REFERENCES

1. Adams OR. Lameness in Horses. 4th ed. Philadelphia: Lea and Febiger, 1985: 486-499.

2. Obel N. Studies on the histopathology of acute laminitis. Dissertation, Almqvist & Wiksell, Uppsala, Sweden. 1948.

3. Garner HE, Coffman JR, Hahn AW, Hutcheson DP, Tumbleson ME. Equine laminitis of alimentary origin: An experimental model. Am J Vet Res 1975; 36: 441-444.

4. Moore JN, Garner HE, Coffman JR. Haematological changes during development of acute laminitis hypertension. Eq Vet J 1981; 13: 240-242.

5. Coffman JR, Johnson JH, Guffy MM, Finocchio EJ. Hoofcirculation in equine laminitis. JAVMA 1970; 156: 76-83.

6. Hood DM, Amoss MS, Hightower C, Mcdonald DR, McGrath JP, McCallum WC, Scratchfield WL. Equine laminitis I: Radioisotopic analysis of the hemodynamics of the foot during the acute disease. J Eq Med Surg 1978; 2: 439-445.

7. Boosman R, Nemeth F. Pathogenesis and drug therapy of acute laminitis in horses: a review. Tijdschr Diergeneeskd 1988; 113: 1237-1246.

8. Marks G. Makroskopische, licht- und elektonen optische Untersuchung zur Morphologie des Hyponychiums bei der Hufrehe des Pferdes. Thesis Freien Universität Berlin, 1984.

9. Nilsson SA. Clinical, morphological and experimental studies of laminitis in cattle. Acta Vet Scand [Supp] 1963; 4: 124-139.

10. Maclean CW. Observations on acute laminitis of cattle in South Hampshire. Vet Rec 1965; 77: 662-672.

11. Morrow DA. Laminitis in cattle. Vet Med 1966; 61: 138-140.

12. Toussaint-Raven E. Lameness in cattle and foot care. Tijdschr Diergeneeskd 1971; 96: 1244-1264.

13. Andersson L. Frequency studies and clinical observations in bovine laminitis. Nord Vet Med 1980; 32: 301-307.

14. Peterse DJ. Prevention of laminitis in Dutch dairy herds. Proceedings IVth symposium on disorders of the ruminant digit 1982; Paris.

15. Mortensen K, Hesselholt M. Laminitis in Danish dairy cattle - an epidemiological approach. Proceedings IVth symposium on disorders of the ruminant digit 1982; Paris.

16. Bazeley K, Pinsent PJN. Preliminary observations on a series of outbreaks of acute laminitis in dairy cattle. Vet Rec 1984; 115: 619-622.

17. Livesey CT, Flemming FL. Nutritional influence on laminitis, sole ulcer and bruised sole in Friesian cows. Vet Rec 1984; 114: 510-512.

18. Andersson L, Bergman A. Pathology of bovine laminitis especially as regards vascular lesions. Acta Vet Scand 1980; 21: 555-566.

19. Greenough PR, MacCallum FJ, Weaver AD. Lameness in Cattle, 2nd ed. Philadelphia, Toronto: J.B. Lippincott Company, 1981.

20. Greenough PR, Gacek Z. A preliminary report on a laminitis like condition occurring in bulls under feeding trials. Proceedings Vth symposium on disorders of the ruminant digit 1986; Dublin. 63-68.

21. Maclean CW. A post-mortem X-ray study of laminitis in barley beef animals. Vet Rec 1970; 86: 457-462.

22. Maclean CW. Observations on laminitis in intensive beef units. Vet Rec 1966; 78: 223-231.

23. Murphy PA, Hanan J, Monaghan M. A survey of lameness in beef cattle housed on slats and straw. In: Wierenga HK, Peterse DJ, eds. Cattle Housing Systems, Lameness and Behaviour. Boston: Martinus Nijhoff, 1987: 67-72.

24. Takahashi K, Young BA. Effects of grain overfeeding and histamine injection on physiological responses related to acute bovine laminitis. Jpn J Vet Sci 1981; 43: 375-385.

25. Peterse DJ. Nutrition as a possible factor in the pathogenesis of ulcers of the sole in cattle. Tijsdschr Diergeneeskd 1979; 104: 966-970.

26. Peterse DJ. De beoordeling van de runderklauw op basis van het optreden van zoollaesies. Thesis Rijksuniversiteit Utrecht,1980.

27. Peterse DJ, Korver S, Oldenbroek JK, Talmon FP. Relationship between levels of concentrate feeding and incidence of sole ulcers in dairy cattle. Vet Rec 1984; 115: 629-630.

28. Peterse DJ, Van Vuuren AM, Ossent P. The effects of daily concentrate increase on the incidence of sole lesions in cattle. Proceedings Vth symposium of disorders of the ruminant digit 1986; Dublin. 39-46.

29. Mortensen K, Hesselholt M. The effects of high concentrate diet on the digital health of dairy cows. Proceedings of the international production congress 1986; Belfast.

30. Greenough PR. The sub-clinical laminitis syndrome. Bovine Practitioner 1985; 20: 144 -149.

31. Smart ME. Relationship of sub-clinical laminitis and nutrition in dairy cattle: a Canadian experience. Proceedings Vth symposium on disorders of the ruminant digit 1986; Dublin. 51-62.

32. Greenough PR, Vermunt J, Gazek Z. Hemorrhage adjusted severity (H.A.S.) score. A practical approach to evaluating sub-clinical laminitis and associated lesions in a dairy herd. 1989 "Submitted for publication".

33. Greenough PR, Vermunt J, Christensen D. The potential parameters of stress in respect to solear hemorrhages in a group of Holstein heifers. 1989. "Submitted for publication".

34. SAS Institute Inc. SAS users guide: statistics, version 5. ed. Cary, NC: SAS Institute Inc, 1985.

35. Steel RGD, Torrie JH. Principles and procedures of statistics. A biometrical approach. New York: McGraw-Hill Book Company, 1980.

36. Prentice DE. Growth and wear rates of hoof-horn in Ayrshire cattle. Res Vet Sci 1973; 14: 285-287.

37. Clark AK, Rakes AK. Effects of methionine hydroxy analog supplementation on dairy cattle hoof growth and composition. J Dairy Sci 1982; 65: 1493-1502.

38. McKinnon JJ, Cohen RDH. Department of Animal and Poultry Science, University of Saskatchewan, Saskatoon, Canada: Unpublished data. 1989.

39. Berg RT, Butterfield RM. New Concepts of Cattle Growth. Sydney: Sydney University Press, 1976: 13-43.

40. Ekfalk A, Funquist B, Jones B, Obel N. Presence of receptors for epidermal growth factor (EGF) in the matrix of bovine hoof - a possible new approach to the laminitis problem. J Vet Med A 1988; 35: 321 - 330.

41. Rheinwald JG, Green H. Epidermal growth factor and the multiplication of cultured human epidermal keratinocytes. Nature 1977; 265: 421-424.

42. Blood DC, Radostits OM. Veterinary Medicine, 7th ed. London: Bailliere Tindall, 1989: 297.

43. Hale WH. Liver abscess and founder. Animal Health and Nutrition 1985: 12-20.

44. Lyford Jr. SJ. Growth and development of the ruminant digestive system. In: Church DC, ed. The Ruminant Animal, Digestive Physiology and Nutrition. Englewood Cliffs, New Jersey: Prentice Hall, 1988: 44-63.

45. Huntington GB. Nutritional problems related to the gastro-intestinal tract: acidosis. In: Church DC, ed. The Ruminant Animal, Digestive Physiology and Nutrition. Englewood Cliffs, New Jersey: Prentice Hall, 1988: 474-480.

46. Rowland AC. Some aspects of the rumenitis/ liver abscess complex in traditional and in intensively managed beef cattle. Vet Rec 1966; 78: 713-716.

47. Dougherty RW, Coburn KS, Cook HM, Allison MJ. Preliminary study of appearance of endotoxin in circulatory system of sheep and cattle after induced grain engorgement. Am J Vet Res 1975; 36: 831-832.

48. Nagaraja TG, Bartley EE, Fina LR, Anthony DH. Relationship of rumen gram-negative bacteria and free endotoxin to lactic acidosis in cattle. J Anim Sci 1978: 47: 1329-1336.

49. Andersen PH, Jarlov N, Hesselholt M. Pathophysiology of experimental bovine endotoxicoses I: Endotoxin in vivo, clearance in healthy and hepatic lipidotic cattle. Proceedings 15th world buiatrics congress 1988; Palma de Mallorca, Spain. 1410-1414.

50. Mortensen K, Hesselholt M, Basse A. Pathogenesis of bovine laminitis (diffuse aseptic pododermatitis). Experimental models. Proceedings XIVth world congress on diseases of cattle 1986; Dublin. 1025-1030.

51. Byyuy RL, Orth DN, Cohen S, Doyne ES. Epidermal growth factor. Effects of androgen and adrenergic agents. Endocrinology 1974; 95: 776-782.

52. Dirks C. Makroscopische, licht-und elektronen-mikroscopische Untersuchungen über den Rückenteil der Rinderklaue. Thesis Freien Universität Berlin, 1985.

53. Maclean CW. The histopathology of laminitis in dairy cows. J Comp Path 1971; 81: 563-569.

54. Boosman R, Koeman J, Nap R. Histopathology of the bovine pododerma in relation to age and chronic laminitis. In press.

55. Smith HA, Jones TC, Hunt RD. Disturbances of circulation. In: Veterinary Pathology. 4th ed. Philadelphia: Lea and Febiger, 1972 : 104-144.

56. Jubb KVF, Kennedy PC, Palmer N. Pathology of Domestic Animals. vol 3. 3rd ed. Toronto: Academic Press, 1985. 42.

57. Boosman R, Mutsaers CWAAM. Arteriography of the bovine claw in relation to chronic laminitis. Proceedings XVth world buiatrics congress 1988; Palma de Mallorca. 1077-1082.